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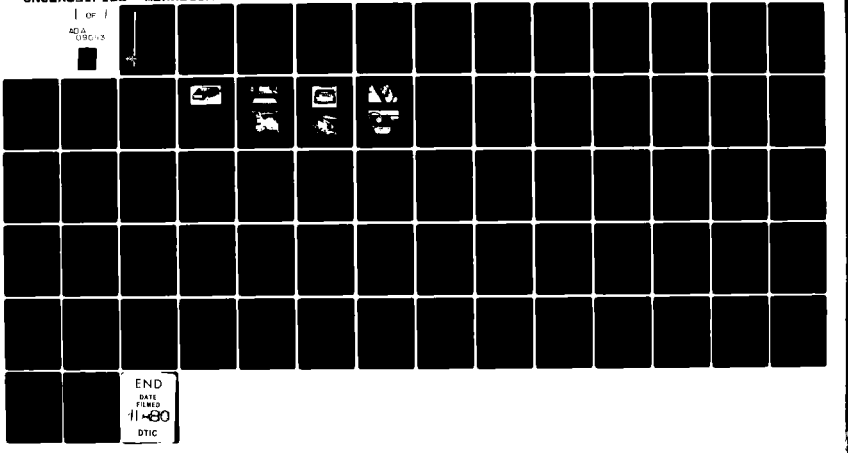

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BASELINE TESTS OF THE ELECTRA VAN MODEL 1000 ELECTRIC VEHICLE

by

Edward J. Dowgiallo, Jr.
Ivan R. Snellings
William H. Blake
and
Kevin F. Krause

July 1980

U.S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT COMMAND
FORT BELVOIR, VIRGINIA

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The Electra Van Model 1000, an electric half-ton multipurpose van, was tested at MERADCOM as part of a Department of Energy project to characterize the state-of-the-art of electric vehicles. The Electra Van is manufactured in Austin, Texas by Jet Industries, Inc. It is powered by 24, 6-volt batteries that are connected to the motor through an SCR controller actuated by a foot pedal to control motor speed. The 28-horsepower motor drives the rear wheels through a three-speed manual transmission. No regenerative braking is provided.

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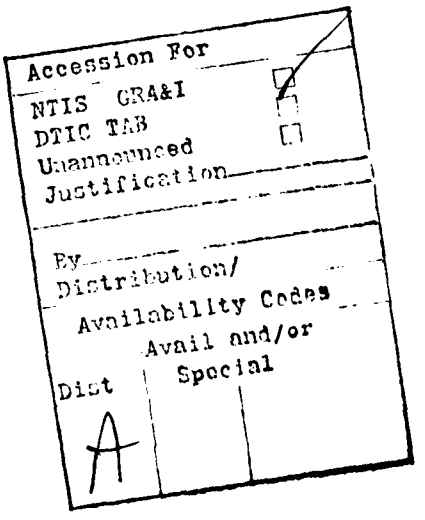
PREFACE

The Electric and Hybrid Vehicle Test was conducted by the US Army Mobility Equipment Research and Development Command (MERADCOM) under the guidance of the US Department of Energy (DOE).

Michael E. Johnson of VSE Corporation was responsible for aspects of calibration of the signal conditioning circuits and recording instruments as well as data tabulations, plotting, and preparation of the report.

Computer programming and some data tabulations and plots were made by David Scott and Arthur Nickless of the Systems Technology & Management Division, Management Information Systems Directorate, MERADCOM.

James A. Queen and Calvin T. Bushrod of the Environmental & Field Division, Product Assurance & Testing Directorate, assisted in vehicle operation and data collection.



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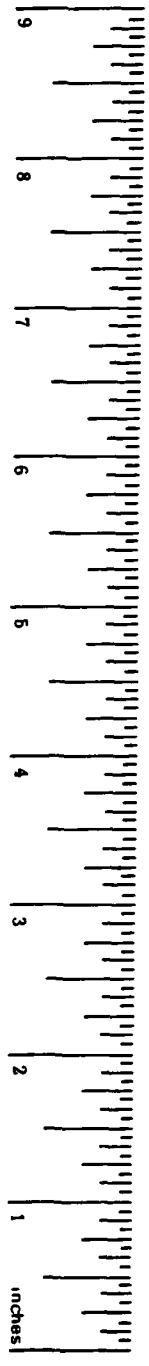
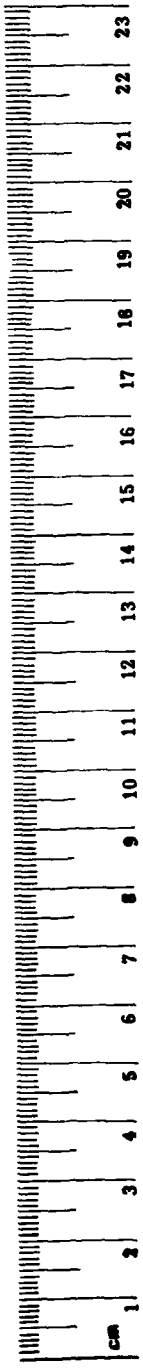
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	metric tons	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	L
pt	pints	0.47	liters	L
qt	quarts	0.95	liters	L
gal	gallons	3.8	liters	L
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

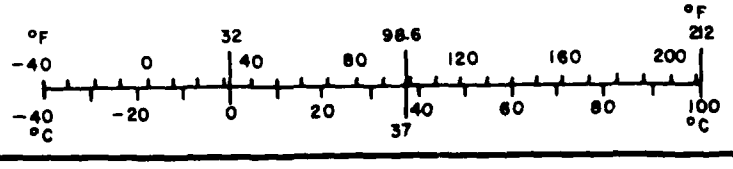
* 1 in = 2.54 cm (exactly).





Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10 000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	metric tons (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
L	liters	2.1	pints	pt
L	liters	1.06	quarts	qt
L	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



BASELINE TESTS OF THE ELECTRA VAN

MODEL 1000 ELECTRIC VEHICLE

I. SUMMARY

The Electra Van Model 1000 is a vehicle manufactured by Jet Industries Inc.; 4201 South Congress Ave; Austin, Texas 78745. The vehicle was tested under the direction of the US Army Mobility Equipment Research and Development Command (MERADCOM) between 20 September 1978 and 28 November 1978. The tests are part of a Department of Energy (DOE) project to assess the state-of-the-art of electric vehicles and to verify manufacturers self-certifications that vehicles offered to DOE site operations meet DOE performance standards.

The Jet Electra Van 1000 is a Dodge Van converted to an electric vehicle which can hold two passengers plus cargo. The vehicle does not have regenerative braking.

The parameters, symbols, units, and unit abbreviations used in this report are given in Table 1. The results of the tests are summarized in Table 2.

II. INTRODUCTION

The vehicle tested and the data presented in this report are in support of Public Law 94-413 enacted by Congress on 17 September 1976. The law requires the Department of Energy to develop data characterizing the state-of-the-art with respect to electric and hybrid vehicles. The data so developed are to serve as a baseline to compare improvements in electric and hybrid vehicle technologies, to assist in establishing performance standards for electric and hybrid vehicles, and to guide future research and development activities. This vehicle was also tested to verify that it complied with DOE performance standards published in the Federal Register 30 May 1978.

The US Army Mobility Equipment Research and Development Command (under the direction of the Electric and Hybrid Research, Development, and Demonstration Division Office; Transportation Programs; DOE) has conducted track tests of electric vehicles to measure their performance characteristics. The tests were conducted using a DOE test procedure "ERDA-EHV-TEP," described in Appendix E of MERADCOM Report 2244.[1] U.S. customary units were used in the collection and reduction of the data and then were converted to the International System of Units for presentation in this report.

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[1] E. J. Dowgiallo, Jr.; C. E. Bailey, Jr.; I. R. Snellings; and W. H. Blake; "Baseline Tests of the EVA Metro Electric Passenger Vehicle," MERADCOM Report 2244 (May 1978).

Table 1. Parameters, Symbols, Units, and Unit Abbreviations

Parameter	Symbol	SI Units		US Customary Units	
		Unit	Abbreviation	Unit	Abbreviation
Acceleration	a	meter per second squared	m/s^2	mile per hour per second	mi/h/s
Area	–	square meter	m^2	square foot: square inch	ft^2 : $in.^2$
Energy	–	megajoule	MJ	kilowatt hour	kWh
Energy Consumption	e	megajoule per kilometer	MJ/km	kilowatt hour per mile	kWh/mi
Energy Economy	–	megajoule per kilometer	MJ/km	kilowatt hour per mile	kWh/mi
Force	p	newton	N	pound force	lbf
Integrated Current	–	ampere hour	Ah	ampere hour	Ah
Length	–	meter	m	inch: foot: mile	in.: ft: mi
Mass: Weight	w	kilogram	kg	pound mass	lbm
Power	p	kilowatt	kW	horsepower	hp
Pressure	–	kilopascal	kPa	pound force per square in.	$lbf/in.^2$
Range	–	kilometer	km	mile	mi
Specific Energy	–	megajoule per kilogram	MJ/kg	watt hour per pound mass	Wh/lbm
Specific Power	–	kilowatt per kilogram	kW/kg	kilowatt per pound mass	kW/lbm
Speed	v	kilometer per hour	km/h	mile per hour	mi/h
Volume	–	cubic meter	m^3	cubic inch: cubic foot	$in.^3$: ft^3

Table 2. Summary of Tests of the Jet Electra Van 1000

Range Test		Range		Power	Road Energy		Energy Economy	
(km/h)	(mi/h)	(km)	(mi)	(kW)	(MJ/km)	(kWh/mi)	(MJ/km)	(kWh/mi)
40	25	71.6	44.5	11.1	0.933	0.417	1.56	0.697
55	34	40.4	25.1	18.1	1.13	0.505	2.51	1.12[a]
		38.4	23.9				2.70	1.21[a]
		48.7	30.3	16.8	1.13	0.507	2.14	0.958
70.8	44	35.8	22.2	24.4	1.27	0.566	2.62	1.17
"B" Cycle		48.2	30.0				2.68	1.20[b]
		56.8	35.3				2.28	1.02
		53.0	32.9				2.30	1.03

Accleration: 0 to 50 km/h (31.2 mi/h) in 15.0 s @ 100-percent charge.

Gradeability Limit: Start and climb a 26.5-percent grade for at least 20 s, based on calculations from a drawbar pull test in first gear at 80-percent DOD. Based on calculations from gear ratios, and without taking wheel slippage into account, the vehicle has a reverse gear gradeability limit of 31.5 percent.

Gradeability at Speed: At 25 km/h can traverse a 13.8-percent grade based on calculations from acceleration tests.

[a] These runs are included for completeness and because of problems encountered are not considered indicative of vehicle performance.

[b] This test was run with batteries which displayed problems and which were replaced following the test.

III. OBJECTIVES

The objectives of the track tests were to determine vehicle and component characteristics and efficiencies. The characteristics of interest are:

Vehicle Speed.
Range and Constant Speed.
Range Over Stop-and-Go Driving Schedules.
Maximum Acceleration.
Gradeability at Speed.
Gradeability Limit.
Road Energy Consumption.
Road Power.
Indicated Energy Consumption.
Braking Capability.
Battery Characteristics.

IV. DESCRIPTION OF TEST VEHICLE

The Jet Industries Electra Van 1000 is an electrified Dodge Van, designed to hold two passengers plus cargo (Figure 1). The batteries, configured as three packs of 6, 8, and 10 (24 total), are Globe Union batteries producing a nominal 144 V, 150 Ah. Two packs are located under the rear deck in the cargo section of the van (Figures 2 and 3; Figure 2 shows configuration). These packs are placed to balance with a heavy ladder which is ordinarily mounted on the left side of the vehicle. The final pack is located along with the drive motor in the inside front of the vehicle (Figure 4). Figure 5 shows the front of the vehicle with the hood open. The controller electronics and front batteries are shown in Figure 6. The interior of the van is the same as a stock van except for state-of-charge, voltage and current meters. Also, there is a safety interlock, the "energize" button so labeled on the dashboard, which must be pushed after turning the ignition key before the arming relay is energized and the propulsion circuits becomes "live" (Figure 7). The starter button for the gasoline-fired heater is also located on the dashboard (Figure 8).

The vehicle has a standard three-speed manual transmission which is coupled to a General Electric, series-wound, 115.9 kg (255-lb), d.c. motor, which produces 20.9 kW (28 hp) @ 3900 r/min. The SCR controller, also manufactured by General Electric, has a variable current rating of 100 to 350 A. The vehicle has an off-board Lester charger, which operates from a 220-V source, and can produce a peak charge current of 30 A. It is equipped with a 12-hour recharge timer.

The vehicle has front-wheel-disc, rear-wheel-drum brakes and does not utilize regenerative braking. For further details, see Appendix A.

Figure 1. Jet Industries Electra Van 1000.

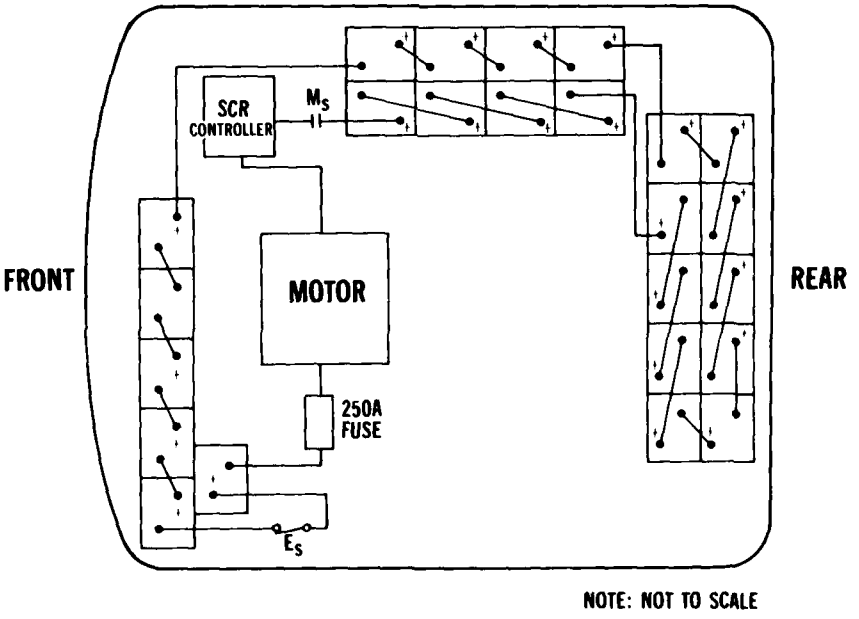

Figure 2. Configuration of Globe Union battery packs.

Figure 3. Battery packs located under the rear deck of the cargo section of the van.

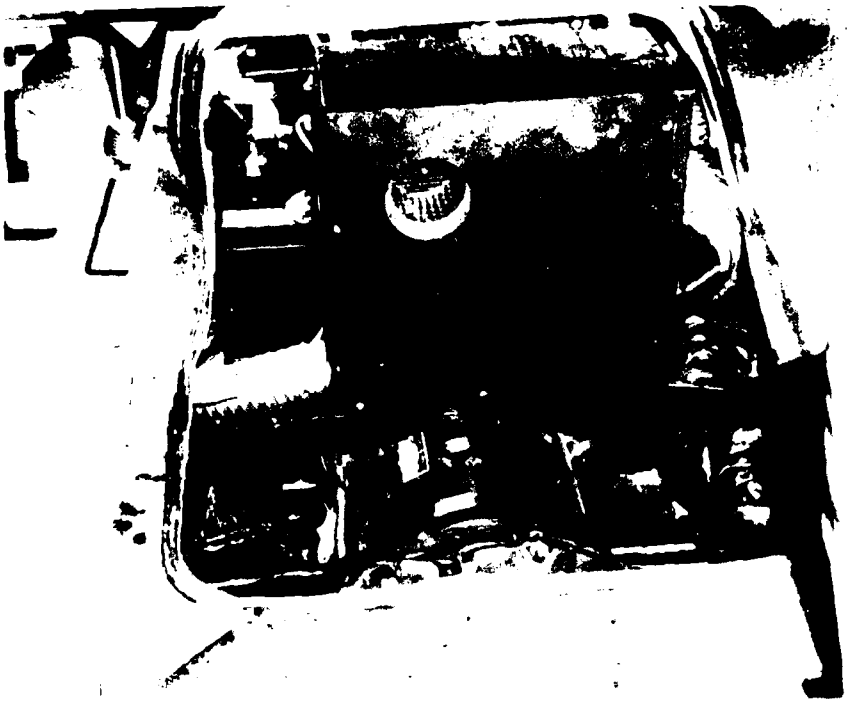

Figure 4. Drive motor, heater, and battery pack located in the inside front of the van.

Figure 5. Front of vehicle with hood open.

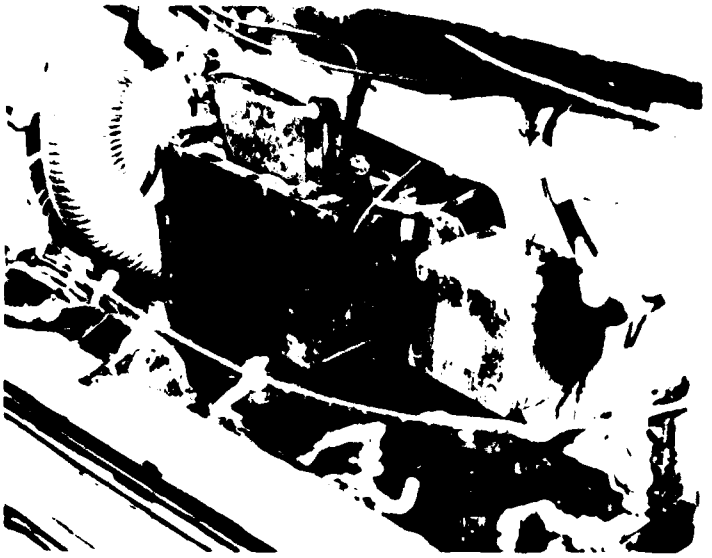

Figure 6. Controller electronics and front battery pack.

Figure 7. Front dashboard with safety interlock "energize" button.

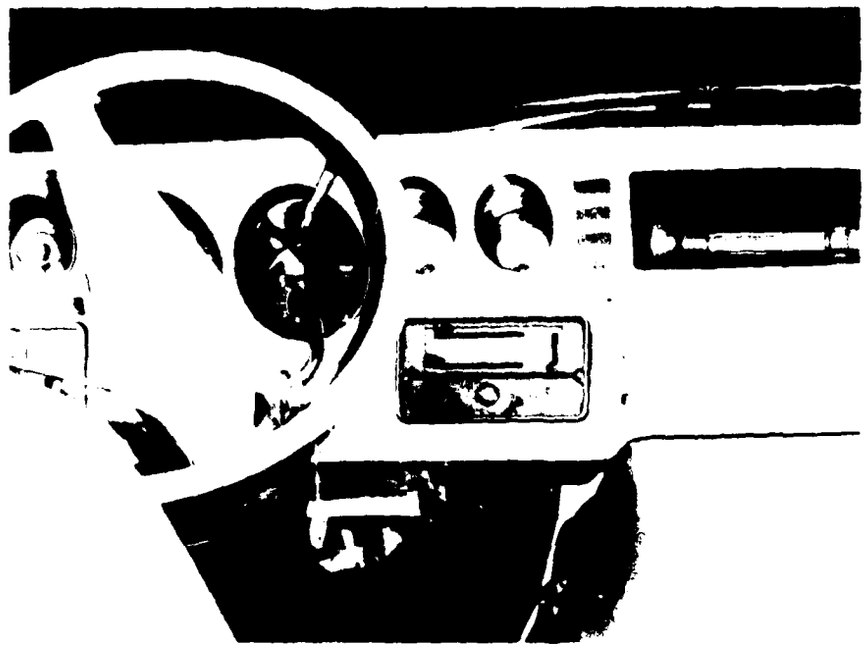

Figure 8. Gasoline-fired heater starter button in the center of the dashboard.

V. INSTRUMENTATION

The Electra Van was instrumented to measure vehicle speed and range, battery voltage, current, "instantaneous" power, and averaged power. The battery charger input in a.c. kilowatt-hours and output in d.c. amperes also were measured. Battery electrolyte temperatures were measured with thermometers. A brief description of the instrumentation system follows:

Instrumentation consisted of signal-conditioning circuits and a magnetic tape recorder for recording analog signals of electrical parameters. Details on the recorder are given in Appendix B of MERADCOM Report 2244.[2] The recorder was operated in the frequency modulation mode at 4.763 cm (1.875 in.) per second. The signal-conditioning circuitry to the recorder consisted of a main battery-voltage divider, a shunt-voltage amplifier for current monitor, an analog multiplier, and averager circuits averaging power and current since the recorder response was less than 0.3 dB down at 500 H. A voltage proportional to battery power was produced by the instantaneous multiplication of voltages proportional to battery voltage and current. Voltages proportional to current and power were both recorded raw and electronically averaged. The raw values include the rapid switching transients associated with the solid-state controller. The overall d.c. measurement error is estimated to be less than ± 1.8 percent for power. This includes digitization from the field-recorded, analog magnetic tape to a computer-compatible, digitized magnetic tape. The measurement error of the various conditioning circuits can be broken down as follows: current shunt (± 0.25 percent), current amplifier (± 1 percent), multiplier (± 0.25 percent), magnetic tape recorder (± 1 percent). In addition to these errors, phase deterioration starts to be significant above 3 kHz when the multiplier is combined with an averager (± 1 percent); and, finally, the analog-to-digital converter at 16 bits and 100 conversions per second did not introduce any significant error.

A diagram of the electric-propulsion system with the instrumentation sensors is shown in Figure 9. A Laboratory Equipment Corporation Tracktest Fifth Wheel with the Model DD1.1 Electronics Digital Speed Meter and the Model DD2.1 Electronic Digital Distance Meter was used during the track tests. A tachometer generator was connected to the fifth wheel to record velocity and calculate distance traveled. The fifth wheel and auxiliaries weighed about 18.6 kg (41 lb). The fifth wheel was calibrated by rotating the wheel on a constant-speed, fifth-wheel calibrator drum mounted on the shaft of a synchronous a.c. motor. The accuracy of the velocity readings was within ± ½ percent of the reading. Velocity was recorded on a Lockheed Store 7 magnetic tape recorder.

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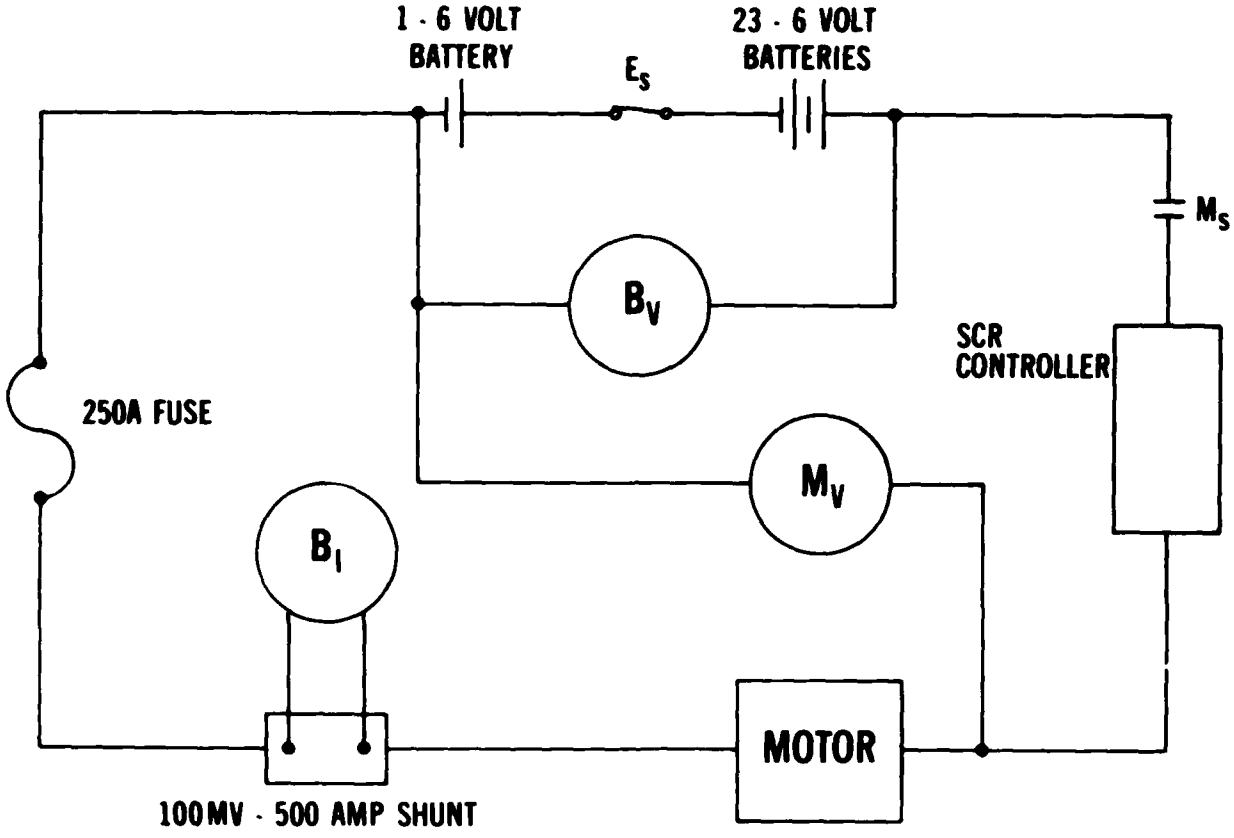
[2] E. J. Dowgiallo, Jr.; C. E. Bailey, Jr.; I. R. Snellings; and W. H. Blake; "Baseline Tests of the EVA Metro Electric Passenger Vehicle," MERADCOM Report 2244 (May 1978).



B_V – BATTERY VOLTAGE
B_I – BATTERY CURRENT
M_V – MOTOR VOLTAGE
M_S – MAIN SWITCH (SOLENOID)
E_S – EMERGENCY SWITCH (MANUAL)

Figure 9. Diagram of electric-propulsion system.

Battery electrolyte temperatures and specific gravities were measured manually before and after the tests.

Power for the fifth-wheel instruments was provided by the vehicle, auxiliary, 12-V SLI battery. The power for the magnetic tape recorder and signal conditioning instrument package was supplied from a battery pack.

All instruments were calibrated before commencing state-of-the -art (SOA) testing with checks before each test.

The current into the battery and the energy into the battery charger were measured while the battery was recharged after each test. The current to the battery was recorded on a Hewlett Packard 7100B strip-chart recorder. The current measurement used a 100-A-100-mV current shunt. The energy delivered to the charger was measured with a Sangamo Electric Type J4S CL200 single-phase, residential, watt-hour meter.

VI. TEST PROCEDURES

When the vehicle was delivered to MERADCOM, the pretest checks described in MERADCOM Report 2244[3] were conducted. Vehicle preparation and test procedures are covered in Appendix B. There was a shakedown run to familiarize the driver with the operating characteristics of the vehicle and to verify proper operation of all instrumentation systems. All tests were run in accordance with the DOE Electric Hybrid Vehicle Test and Evaluation Procedure, Appendix E of MERADCOM Report 2244.[4]

1. Range Tests at Constant Speed. Range tests at constant speed were carried out at 40 km/h (25 mi/h), 56.3 km/h (35 mi/h), and 70.8 km/h (44 mi/h); speeds were held constant within ± 1.6 km/h (1 mi/h), and the test was terminated when the vehicle could no longer maintain 95 percent of the designated test speed.

2. Range Tests Under Driving Schedules. The 32.2-km/h (20-mi/h), SAE J227a, schedule B, was run three times with this vehicle. Complete descriptions of the cycle test procedures are given in Appendix E of MERADCOM Report 2244.[5]

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[3] E. J. Dowgiallo, Jr.; C. E. Bailey, Jr.; J. R. Snellings; and W. H. Blake, "Baseline Tests of the LVA Metro Electric Passenger Vehicle," MERADCOM Report 2244 (May 1978).

[4] *Ibid.*

[5] *Ibid.*

3. Acceleration and Coast-Down Tests. The acceleration-coast-down tests were performed continuously until the battery was discharged. Data were recorded on an analog, magnetic-tape recorder and later digitized, and calculations were performed on a CDC 6600 computer. Data were tabulated for three states of charge. Coast-down data were taken following each maximum-acceleration run with the transmission in neutral. The coast-down speed versus time plot is shown in Figure 10 and the data points are tabulated in Appendix C.

4. Braking Tests. The braking tests were run on the level, straight portion of the MERADCOM loop, to conform to the DOE Electric and Hybrid Vehicle Test and Evaluation Procedure: 2.8.8.3.2.5, Control Forces. Unless otherwise specified, the force applied to a brake control is not less than 15 lbf, not more than 150 lbf, and the maximum allowable stopping distances are tabulated in Table 3.

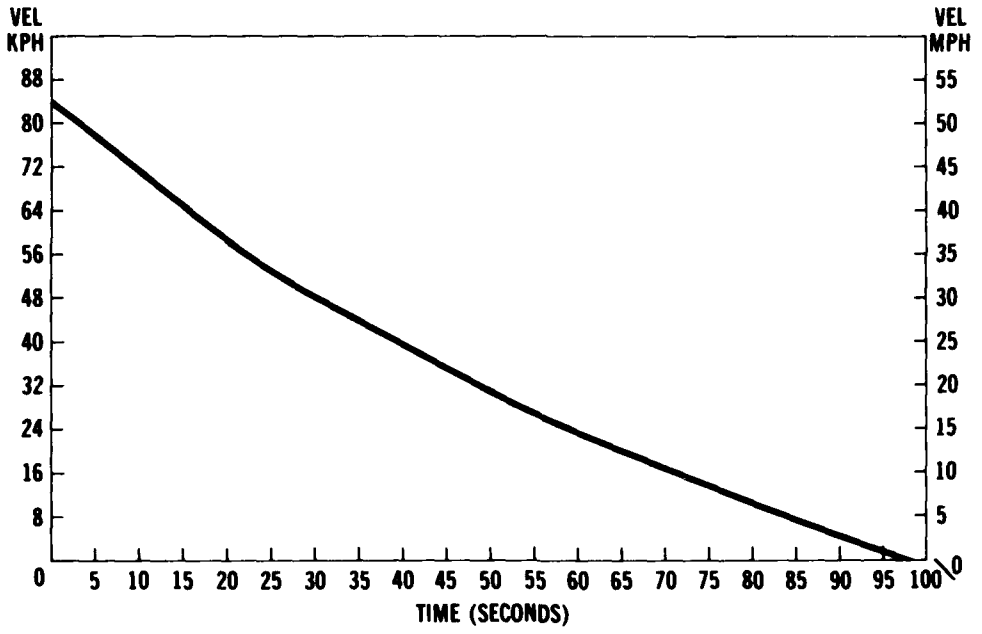

Figure 10. Coast-down speed versus time.

Table 3. Stopping Distances

Vehicle Test Speed (mi/h)	Maximum Stopping Distance (ft)
30	69
35	110
40	144
45	182
50	225

5. Tractive Force Tests. The maximum-grade capability of the test vehicle was determined from tractive force tests by towing an M8 light, field dynamometer at 1.6 km/h (1 mi/h), while the test vehicle was being driven with wide-open throttle. The force was measured by the dynamometer instrumentation from the load cell attached between the vehicles. The test was run with the batteries 0, 40, and 80 percent discharged.

VII. TEST RESULTS AND DISCUSSION

1. Range. The data collected from all range tests are summarized in Table 4 (SI Units) and Table 5 (English Units). The tables show the test data, type of test, environmental conditions, range-test results, and energy into the charger. These data are used to determine vehicle range and energy economy.

2. Maximum Speed. The maximum speed of the vehicle was measured during the acceleration tests. The measured maximum speed was 85.3 km/h (53.0 mi /h) for this vehicle.

3. Maximum Accleration. The maximum acceleration of the vehicle was measured with the batteries fully charged, 40 percent discharged, and 80 percent discharged. The results of the tests are shown in the curves of Figure 11 and are tabulated in Appendix C. The average acceleration, $\bar{a}_n$, was caluclated for the time period, t_{n-1} to t_n, where the vehicle speed increased from V_{n-1} to V_n from the equation,

$$\bar{a}_n = \frac{V_n - V_{n-1}}{t_n - t_{n-1}},$$

Table 4. Summary of Test Results for Electra Van 1000 – SI Units

Test Date	Test Type	Time Start	Wind Start	Temp Start (°C)	Time Finish	Wind Finish	Temp Finish (°C)	Range (km)	Number Cycles	Energy into Charger (MJ)	Indicated Energy Consumption (MJ/km)
16 Oct 78[a]	B Cycle	0827	Calm	5.6	1300	Calm	14.4	48.2	141	104.4	2.17
23 Oct 78	B Cycle	0750	Calm	8.3	1253	WNW 14.5 km/h	28.3	56.8	166	129.6	2.28
25 Oct 78	B Cycle	0747	Calm	3.3	1230	SW 14.5-27.4 km/h	15.0	53.0	155	122.4	2.31
26 Oct 78	40 km/h	0929	WSW 1.6 km/h	18.3	1108	W 11.2 km/h	21.1	71.6	–	111.6	1.56
27 Oct 78	70.8 km/h	0820	Gusts NW 7.4 km/h	11.7	0900	NNW 14.5 km/h	20.1	35.8	–	93.6	2.61
3 Nov 78	56 km/h	0630	Calm	4.4	1230	3.7 km/h	12.2	40.4	–	100.8	2.50
6 Nov 78[b]	56 km/h	–	Calm	5.6	–	Calm	7.8	38.4	–	104.4	2.72
7 Nov 78	56 km/h	0810	Calm	8.9	0905	Calm	13.9	48.3	–	104.4	2.16

[a] After this test, the GE controller was readjusted by a factory representative, and two traction batteries were replaced.

[b] Fifth-wheel generator failure prevented accurate velocity/distance measurement. Distance indicated was obtained from vehicle odometer.

Table 5. Summary of Test Results for Electra Van 1000 – English Units

Test Date	Test Type	Time Start	Wind Start	Temp Start (°F)	Time Finish	Wind Finish	Temp Finish (°F)	Range (mi)	Number Cycles	Energy into Charger (kW-h)	Indicated Energy Consumption (kW-h/mi)
16 Oct 78[a]	B Cycle	0827	Calm	42	1300	Calm	58	30.0	141	36	1.20
23 Oct 78	B Cycle	0750	Calm	47	1253	WNW 9 mi/h	83	35.3	166	36	1.02
25 Oct 78	B Cycle	0747	Calm	38	1230	SW 9-17 mi/h	59	32.9	155	34	1.03
26 Oct 78	25 mi/h	0929	WSW 1 mi/h	65	1108	W 7 mi/h	70	44.5	–	31	0.697
27 Oct 78	44 mi/h	0820	Gusts NW 4.6 mi/h	53	0900	NNW 9 mi/h	69	22.2	–	26	1.17
3 Nov 78	35 mi/h	0630	Calm	40	1230	2.3 mi/h	54	25.1	–	28	1.12
6 Nov 78[b]	35 mi/h	–	Calm	42	–	Calm	46	23.9	–	29	1.21
7 Nov 78	35 mi/h	0810	Calm	48	0905	Calm	57	30.3	–	29	0.958

[a] After this test, the GE controller was readjusted by a factory representative and two batteries were replaced.

[b] Fifth-wheel generator failure prevented accurate velocity/distance measurement. Distance indicated was obtained from vehicle odometer.

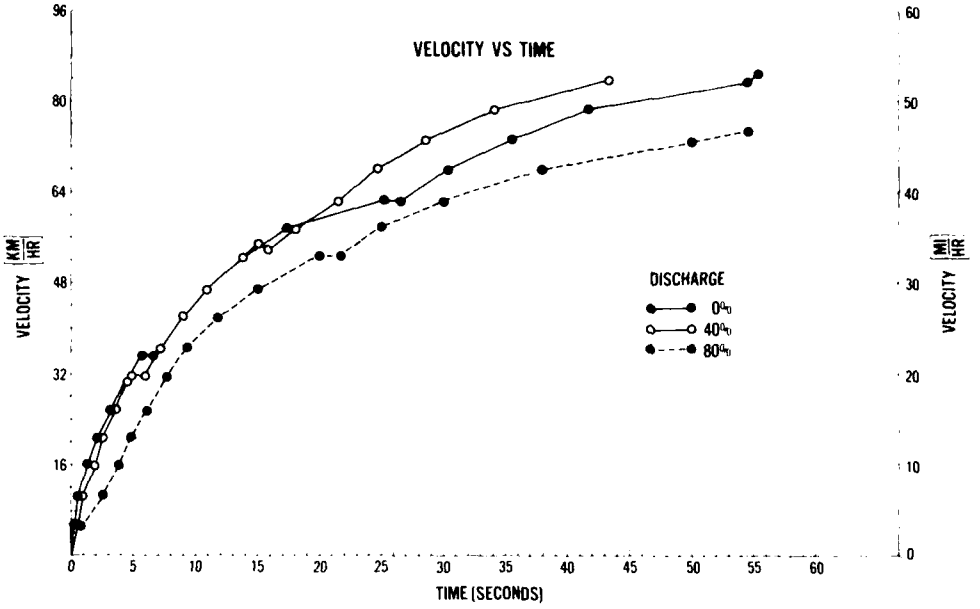

Figure 11. Acceleration test results.

and the average speed of the vehicle V, was calculated from the equation,

$$\overline{V} = \frac{V_n + V_{n-1}}{2} .$$

Average acceleration as a function of speed is shown in Figure 12 and tabulated in Appendix C. The dips in the curve occurred at the shift points. Note that at the second shift point of the 40-percent discharge run, the acceleration goes negative to -0.43 m/s² (1.52 ft/s²).

4. Gradeability. The maximum vehicle speed on a specific grade is determined from maximum acceleration tests by using the equations:

Gradeability, G, at a speed, $\overline{V}$, in km/h:

$$G = 100 \tan (\sin^{-1} 0.1026\ \bar{a}_n)\ \%;$$

or in English units at a speed, $\overline{V}$, in mi/h:

$$G = 100 \tan (\sin^{-1} 0.455\ \bar{a}_n),\ \%;$$

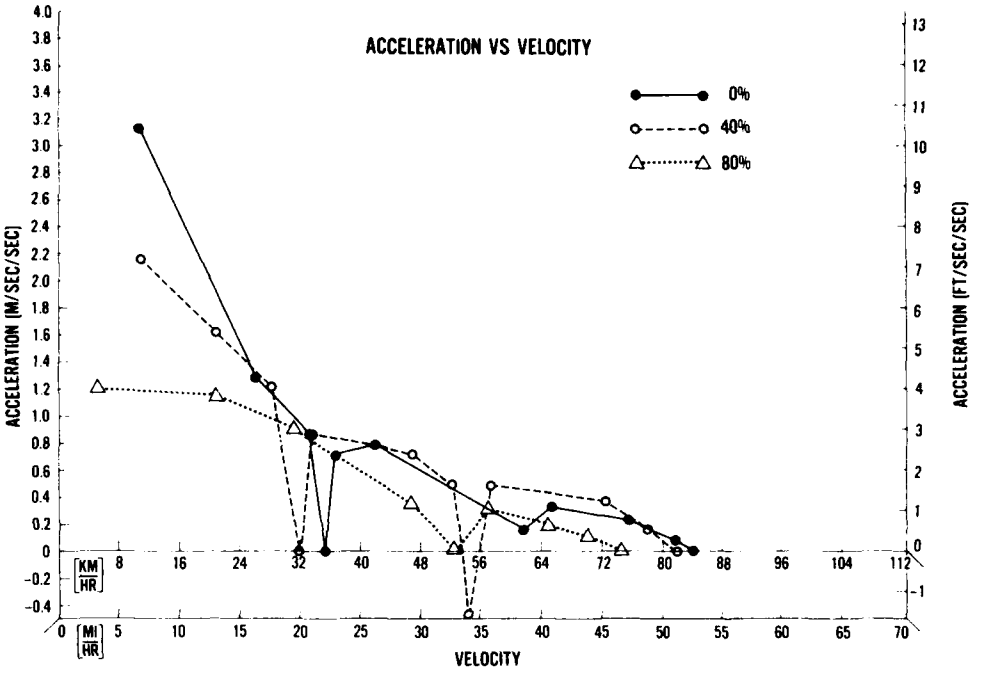

Figure 12. Average acceleration as a function of speed.

where:

$\tilde{a}_n$ = acceleration in meters per second squared (m/s^2) or mi/h/s in the English system.

The resulting maximum grade the Electra Van can negotiate as a function of speed is shown in Figure 13 and is tabulated in Appendix C.

5. Gradeability Limit. Gradeability limit is defined by the SAE J227a procedure as the maximum grade on which the vehicle can just move forward. The limit is determined by measuring the tractive force with a load cell while towing a second vehicle at about 1.6 km/h (1 mi/h). It is calculated from:

$$\text{Gradeability limit in percent} = 100 \tan\left(\sin^{-1} \frac{P}{9.8W}\right)$$

or in English units:

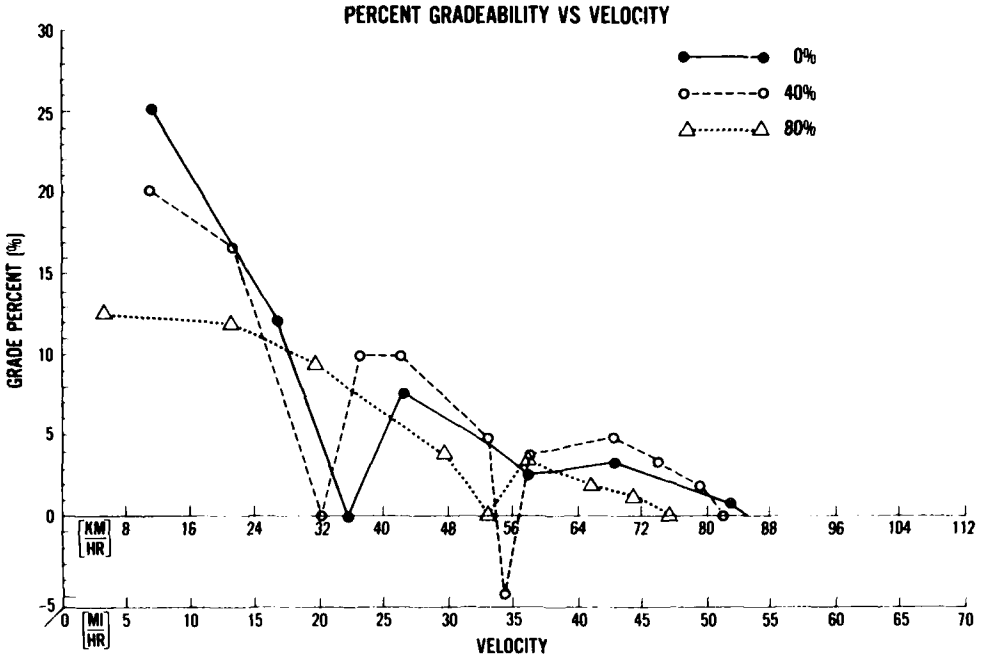

Figure 13. Results of gradeability tests.

$$\text{Gradeability limit in percent} = 100 \tan\left(\sin^{-1} \frac{P}{W}\right)$$

where:

P = Tractive force in newtons, N (lbf).
W = Gross vehicle weight in kg (lb).

The tractive forces that the Jet Van 1000 was capable of exerting for three states of battery discharge were:

0% Discharged — 8388N (1885 lbf)
40% Discharged — 7676N (1725 lbf)
80% Discharged — 7409N (1665 lbf)

All tests were performed in first gear. At a vehicle test weight of 2671 kg (5875 lb), the resulting gradeability limits were:

0% Discharged — 33.9%
40% Discharged — 30.7%
80% Discharged — 29.6%

6. Road-Energy Consumption. Road energy is a measure of the energy consumed in overcoming the vehicle's aerodynamic and rolling resistance plus the energy consumed in the differential drive shaft and the portion of the transmission rotation when in neutral. Road energy is obtained during coast down with the differential being driven only by the wheels.

The road energy consumed by the vehicle at various speeds and the losses in the differential were determined from coast-down tests. Road-energy consumption (E_n) is calculated as megajoules per kilometer from the following equation:

$$E_n = 2.78X10^{-4} W \frac{V_{n-1} - V_n}{t_n - t_{n-1}}, \frac{MJ}{km}$$

or in English units:

$$E_n = 9.07X10^{-5} W \frac{V_{n-1} - V_n}{t_n - t_{n-1}}, \frac{kWh}{mi}$$

where:

V = Vehicle speed in km/h (mi/h)
t = Time (s)

The results for the road-energy determination are shown in Figures 14 and 15 and are tabulated in Appendix C.

7. Road-Power Requirements. The road power is a measure of vehicle aerodynamic and rolling resistance plus the differential, drive shaft, and a portion of the transmission's power loss.

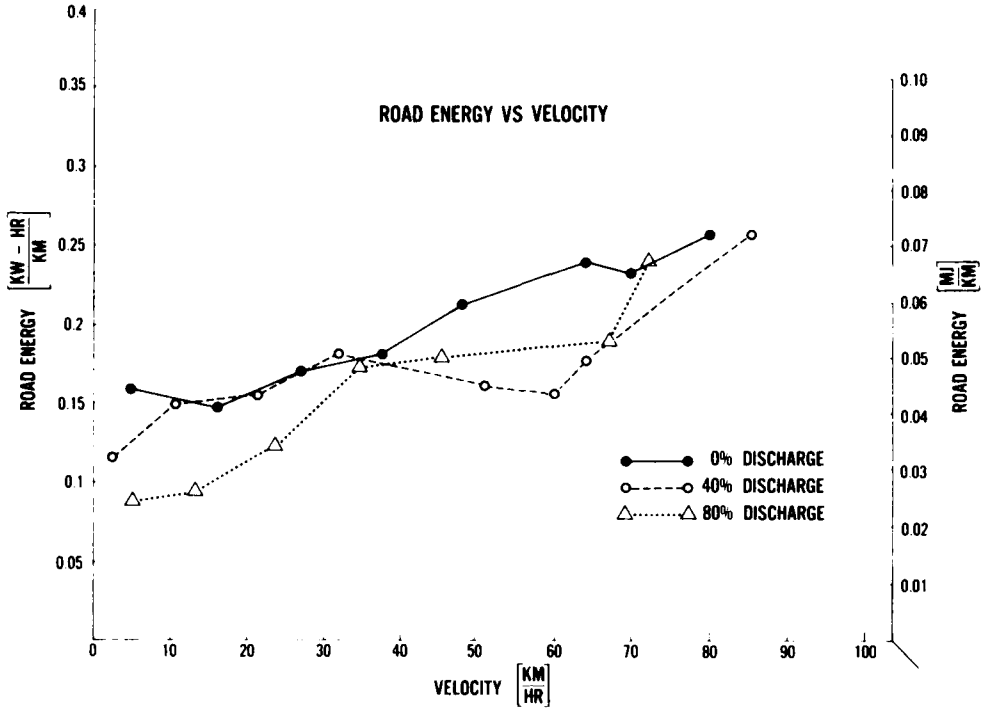

Figure 14. Results of road-energy tests — *SI units.*

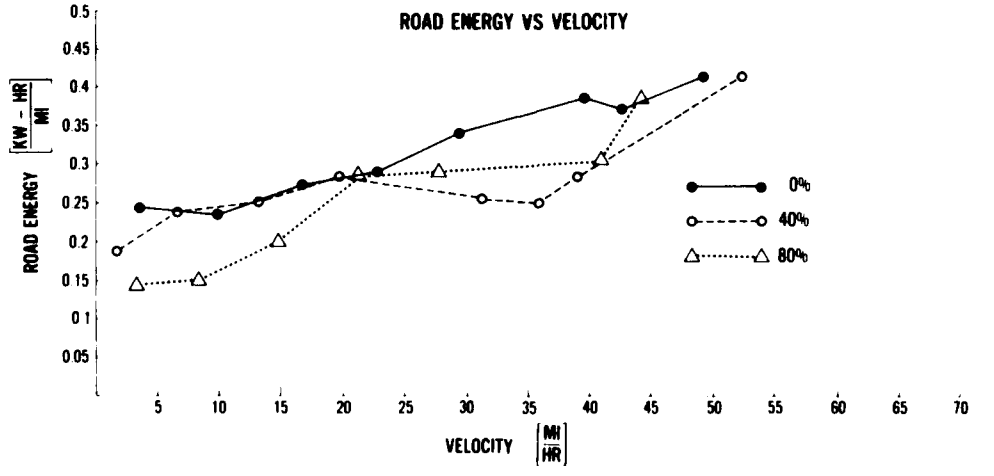

Figure 15. Results of road-energy tests — English units.

The road power, P_n, required to propel a vehicle at various speeds is also determined from the coast-down tests. The following equations are used:

$$P_n = 3.86X10^{-5} W \frac{V^2_{n-1} - V^2_n}{t_n - t_{n-1}}, \text{ kW;}$$

or in English units:

$$P_n = 6.08X10^{-5} W \frac{V^2_{n-1} - V^2}{t_n - t_{n-1}}, \text{ hp.}$$

The results of road-power calculations are shown in Figure 16 and are tabulated in Appendix C.

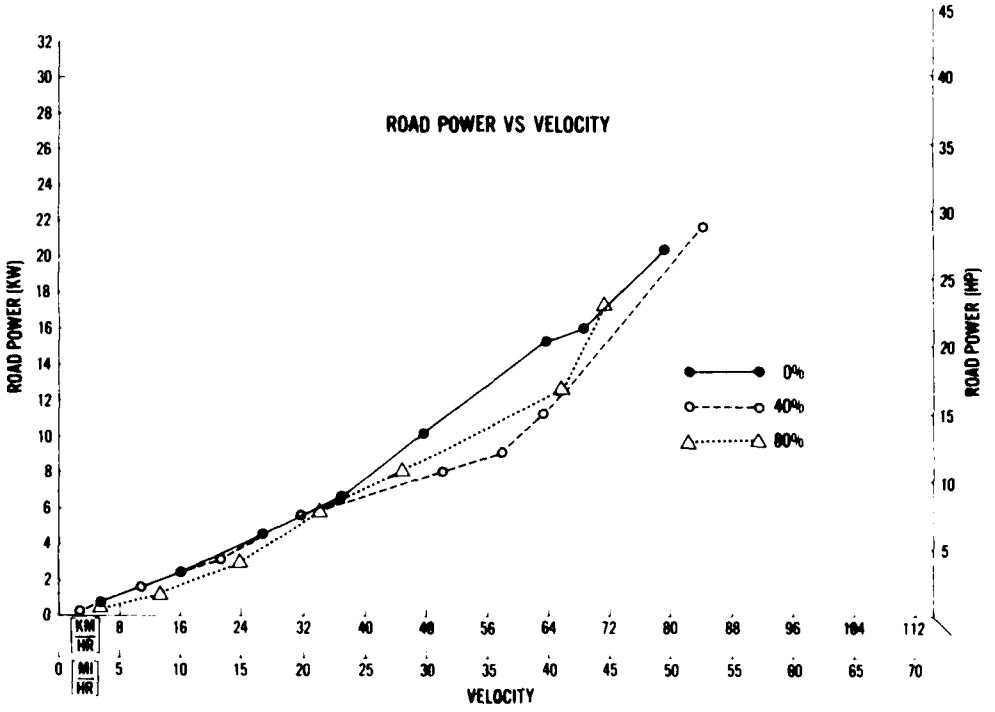

Figure 16. Road-power requirements determined from the coast-down tests.

8. Indicated Energy Consumption. The vehicle indicated energy consumption is defined as the energy required to recharge the battery after a test divided by the vehicle range achieved during the test where the energy is measured as the input to the battery charger.

The energy input to the battery charger was measured with a residential kilowatt-hour meter following each range test. Some overcharge of the batteries was usually required in order to assure that all cells of the batteries were fully charged and the pack was equalized. The energy usage was based on field data acquired with an on-board Lester Corporation charger. The results appear in Tables 4 and 5.

9. Braking Capability. The results of the dry straight-line braking tests are given in Table 6. The vehicle met all dry braking criteria.

Table 6. Braking Capability

Speed		Distance		Pedal Pressure	
(k/h)	(mi/h)	(m)	(ft)	(N)	(lbf)
48.3	30	17.6	57.7	631.9	142
56.3	35	25.1	82.5	649.7	146
64.4	40	34.6	113.7	605.2	136
72.4	45	43.3	151.9	623.0	140
80.4	50	50.6	166.0	623.0	140

VIII. COMPONENT PERFORMANCE AND EFFICIENCY

1. Battery Characteristics.

a. Manufacturer's Data. The Electra Van 1000 used 24 6-volt batteries manufactured by Globe Union. These batteries were hand-built prototypes, and according to the vehicle summary data sheet provided by the manufacturer, were rated at 150 Ah for a 2-hour discharge. Appendix D gives a fuller discussion of the batteries.

b. Battery Acceptance. Prior to initiation of road tests, the batteries supplied by the vehicle manufacturer were tested for battery capacity and terminal integrity as specified in Appendix E of MERADCOM Report 2244.[6] The capacity check was performed with a thyristor controlled discharge unit.[7] The battery system used for the vehicle was discharged at 75A as seen in Figure 17. Appendix D gives further details.

2. Constant Vehicle Speed Battery Performance. During the road tests, battery current and motor voltage were monitored constantly. Since the battery, controller, and motor unit (with its free-wheel diode, forward and reverse contactors, and braking diode) made up a high-current closed loop and the motor unit was constructed so as to make inserting a shunt for current monitor difficult, battery current was monitored and was assumed to be equal to motor (or more accurately to motor unit) current.

The constant speed battery performance of the Jet Van 1000 is given in Figures 18 and 19.

3. Battery Performance — Driving Cycle. The battery current, voltage, power, and velocity averaged over the first three cycles and next to the last three cycles of the 25 Oct 78 "B" cycle start-stop test are given in Figures 20 through 25. The data in these graphs are obtained by averaging the first three cycles and averaging the three cycles just before the last cycle. The Figures 20, 21, and 22 give these averages for propulsion battery current, voltage, and power. Figure 23 shows in detail the average of the velocity of the first three cycles and the next to the last three cycles. Figures 24 and 25 show these averaged velocities separately to include coasting and braking.

IX. VEHICLE RELIABILITY

No major problems with the vehicle were encountered except for the initial battery problems.

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[6] E. J. Dowgiallo, Jr.; C. E. Bailey, Jr.; I. R. Snellings; and W. H. Blake; "Baseline Tests of the EVA Metro Electric Passenger Vehicle," MERADCOM Report 2244 (May 1978).

[7] E. J. Dowgiallo, Jr.; J. B. O'Sullivan; I. R. Snellings; and R. B. Anderson; "High Power Facility for Testing Electrochemical Power Sources," Princeton, New Jersey; *Journal of the Electrochemical Society*, Vol. 121, No. 9 (September 1974).

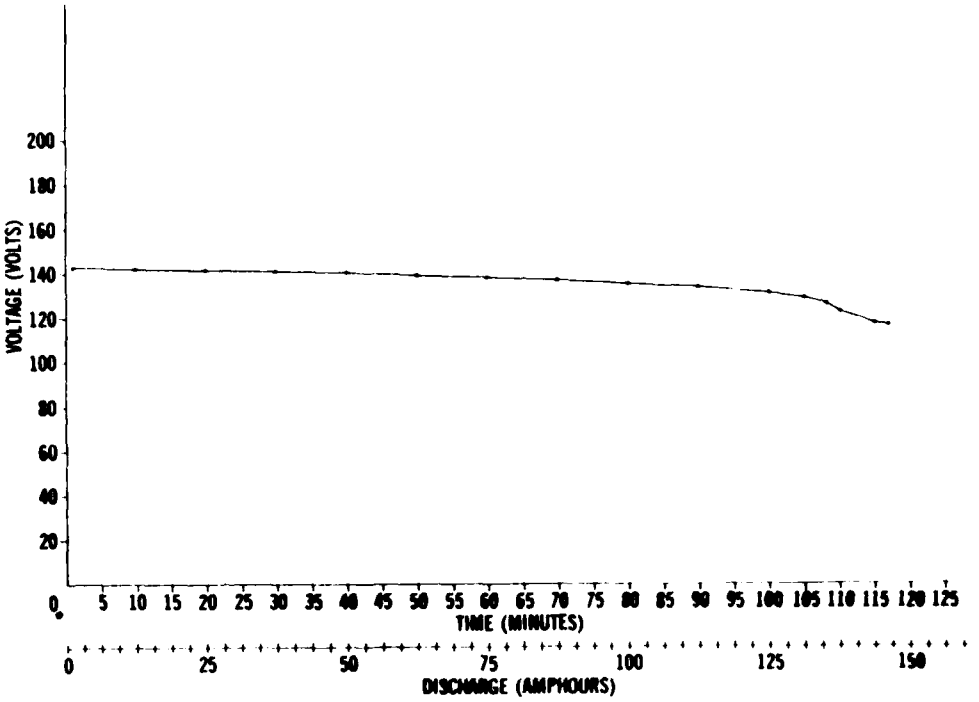

Figure 17. Jet 1000 traction battery, 75-A discharge.

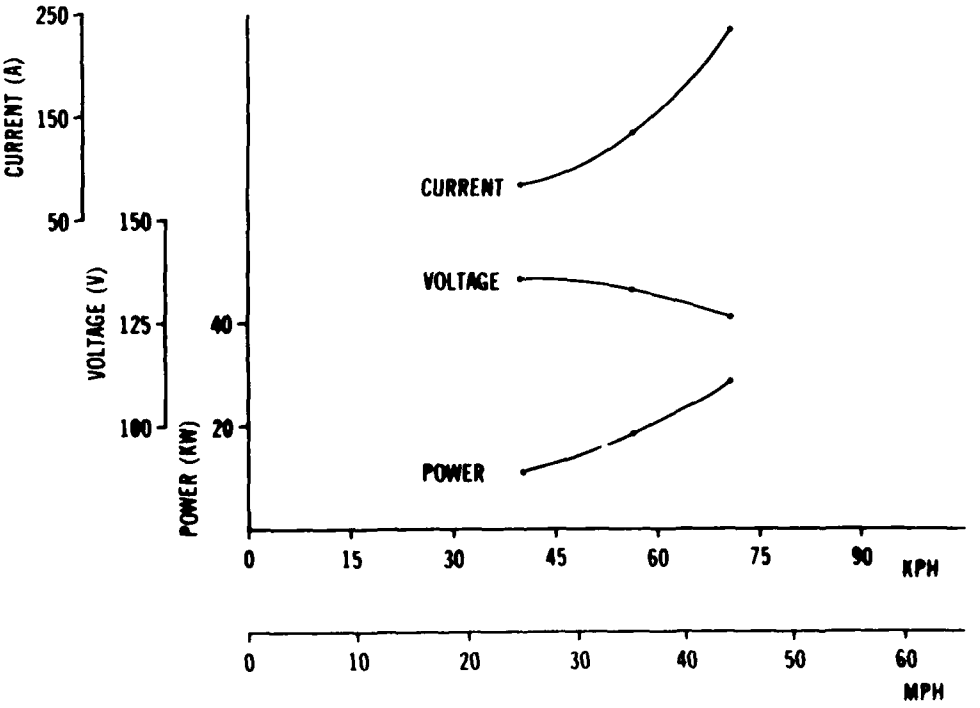

Figure 18. Constant-speed battery performance (first 25 percent of the range).

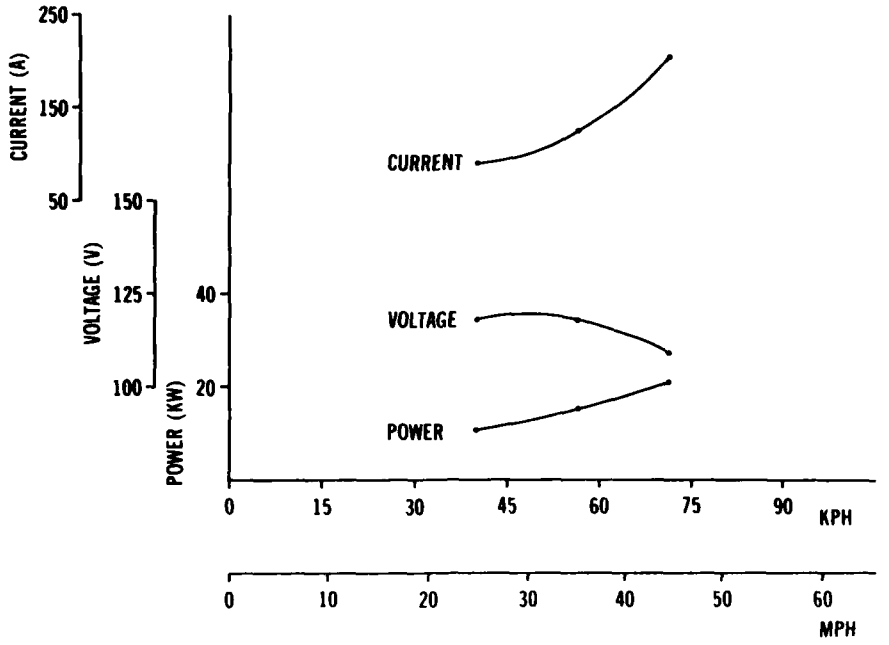

Figure 19. Constant-speed battery performance (last 25 percent of the range).

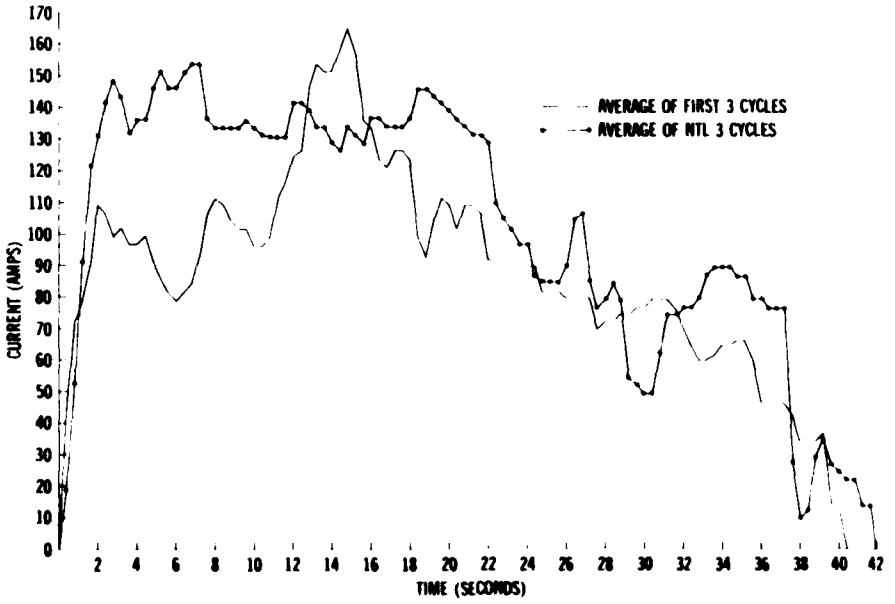

Figure 20. Start/stop average battery current.

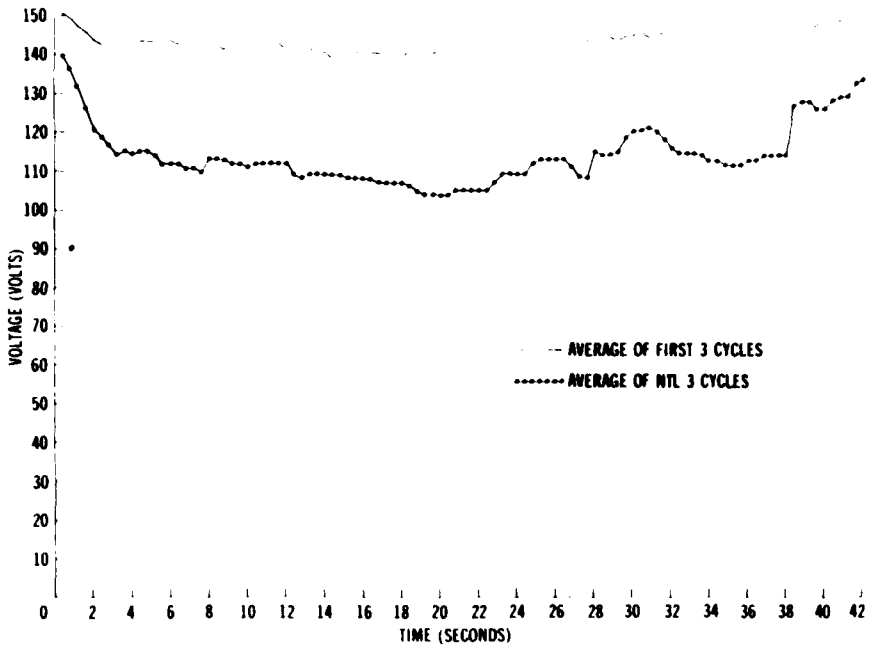

Figure 21. Start/stop average battery voltage.

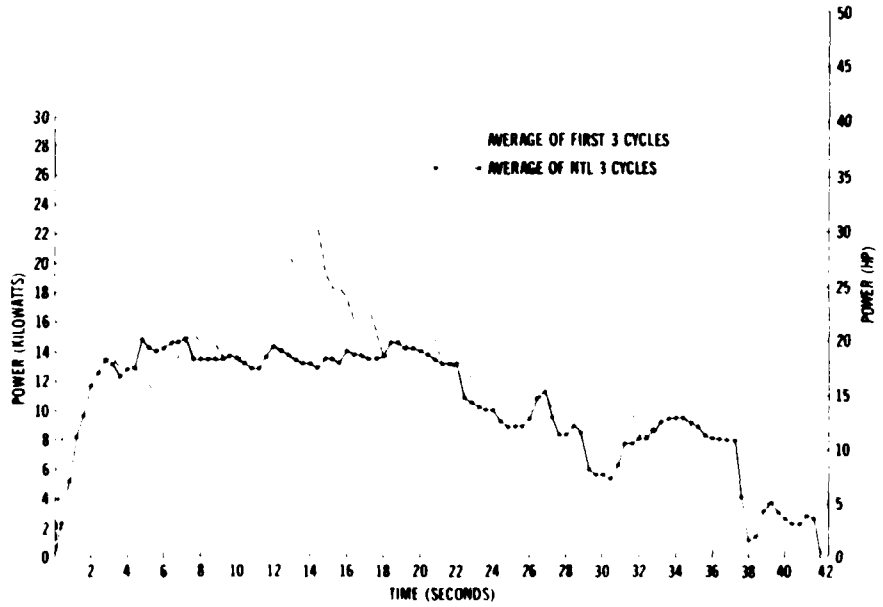

Figure 22. Start/stop average battery power.

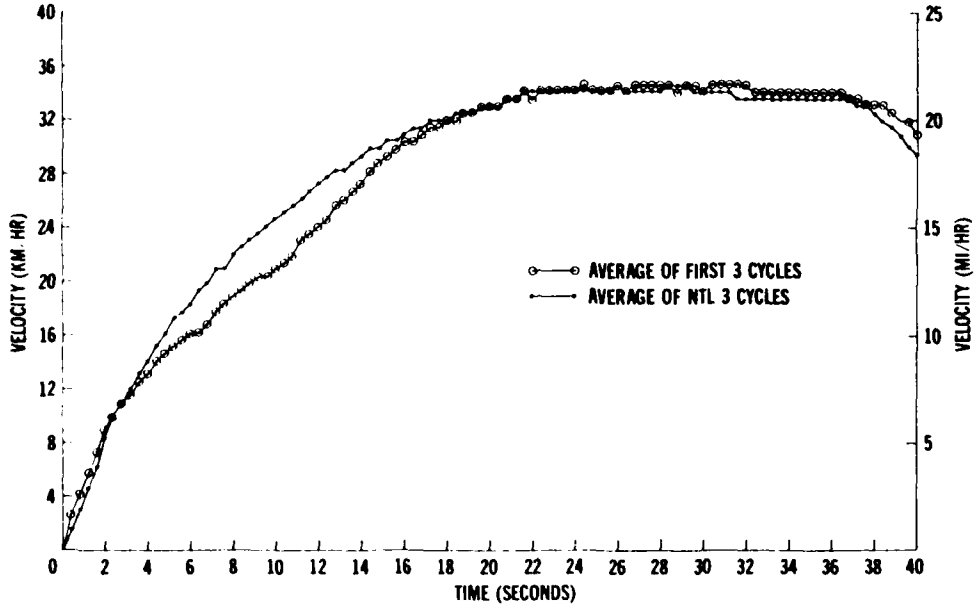

Figure 23. Start/stop average velocity.

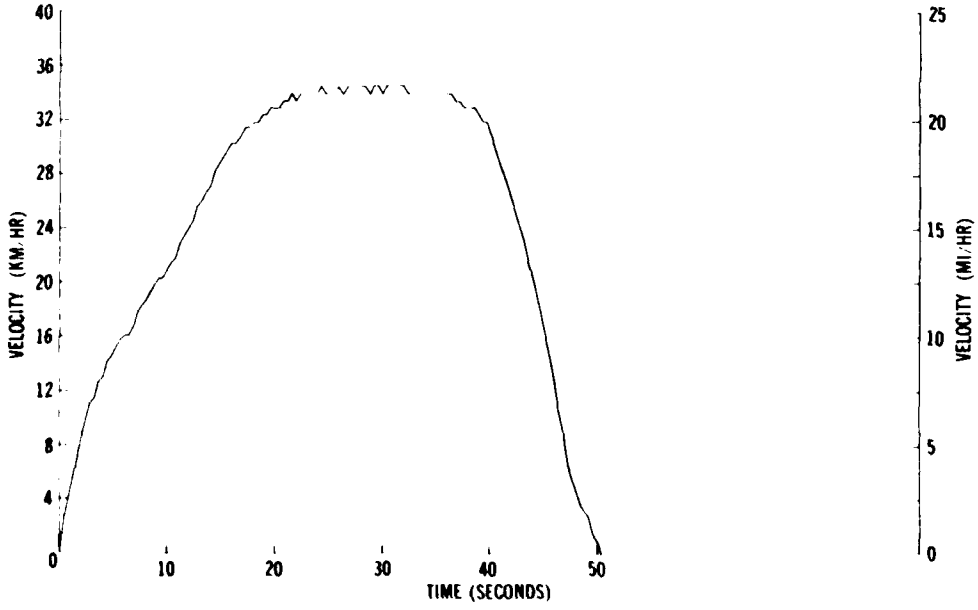

Figure 24. Start/stop average velocity (first three cycles).

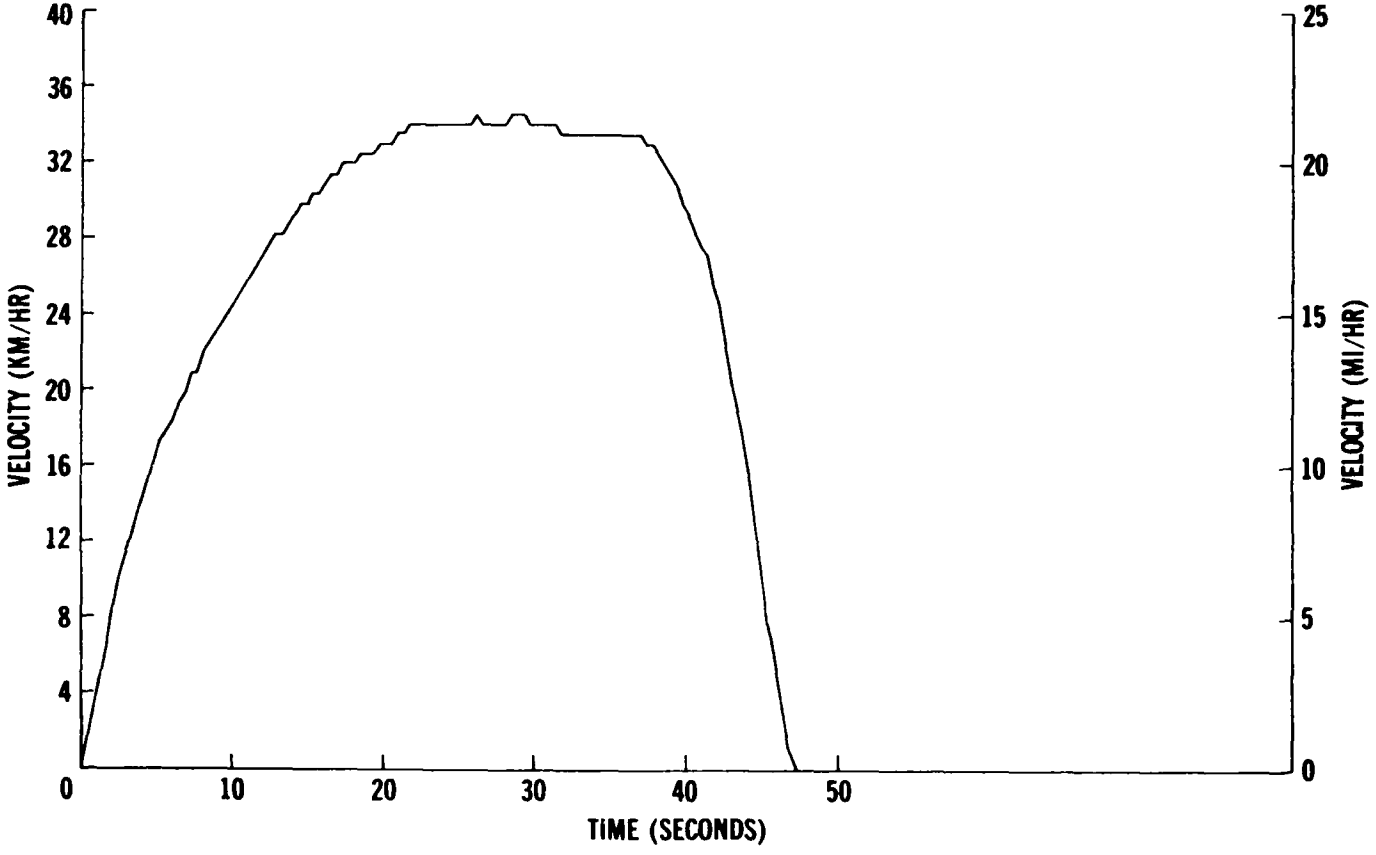

Figure 25. Start/stop average velocity (next to last three cycles).

APPENDIX A

VEHICLE SUMMARY DATA WORKSHEET

1. Vehicle Manufacturer Name and Address

Jet Industries, Inc.
2327 East Ben White Blvd.
Austin, Texas 78741
512-385-0660

2. Vehicle Description

Name: Electra Van
Model: 1000
Availability: 30 Days
Price: $10,600

3. Vehicle Weight

Curb Wt: 4875
Payload Wt: 1000 lb
Gross Wt: 5875 lb

4. Vehicle Size

Wheelbase: 109 in.
Length: 176 in.
Width: 79.82 in.
Headroom: 47.17 in.
Legroom: N/A

5. Auxiliaries & Options

No. Lights: 10
a. Head: Parking: Turn Signal: Running:
b. Brake: Tail Back-up

Windshield Wipers: Yes
Windshield Washers: Yes
Defroster: Yes
Heater: Yes
Radio: No
Fuel Gauge: Yes
Ampmeter: Yes
Tachometer: No
Speedometer: Yes
Odometer: Yes
No. Mirrors: 3
Power Steering: No
Power Brakes: No
Transmission Type: Three-Speed Manual

6. Propulsion Batteries

Type: Lead Acid
Manufacturer: Globe Union
No. of Modules: 4
No. Cells: 72
Battery Voltage: 144
AH Capacity: 150 Ah
Battery Size: 10-5/16 in. X 7-2/16 in. X H 10½ in.
Battery Wt: 70 lb
Battery Age: New
Battery Rate: 2 hr
Battery Cycles: 4

7. Auxiliary Battery

Type: Lead Acid
Manufacturer: SGL
No. Cells: 6
Battery Voltage: 12
AH Capacity: 60 AH
Battery Size: 6-11/16 in. X 10-1/16 in. X 12 in.
Battery Rate: N/A
Battery Wt: 45 lb

8. Controller

Type: SCR
Manufacturer: General Electric
Voltage Rating: 144
Current Rating: Variable 100-350
Size: 11 in. X 16 in.X 7 in.
Weight: 80 lb

9. Propulsion Motor

Type: Series
Manufacturer: General Electric
Insulation Class: H
Voltage Rating: 165 V. Max
Current Rating: 1 hr 175 A
HP Rating: 28 at 3900 r/min
Size: 11 in. Diameter. 18¼-in. Long
Weight: 255 lb
Rated Speed: 3900 r/min

10. Body

Type: Van
Manufacturer: Chrysler
No. Doors: Six
Type: Swing Steel
No. Windows: Seven
Type: Safety Glass
No. Seats: Two
Type: Bucket Seats
Cargo Volume: 208 ft^3
Cargo Dimensions: 117.3 in. L, 65.3 in. W, 47.1 in. H

11. Chassis

Type Frame: Unisteel
Manufacturer: Chrysler
Type Material: Steel
Modifications: None
Type Springs: Leaf Springs
Type Shocks: Regular
Axle Type Front: Straight
Axle Type Rear: Straight
Axle Manufacturer: Chrysler
Drive Line Ratio: 3.55
Type Brakes Front: Disc
Type Brakes Rear: Drum
Regenerative Brakes: No
Tire Type: Bias Ply
Size: 550X15
Pressure: 50 lbf/in^2
Rolling Radius: 13¼

12. Battery Charger

Type: Variable Volt
Manufacturer: Lester
On or Off Board: Off
Input Voltage: 220 V
Peak Current: 30 A
Recharger Time: Yes, 12 hr
Weight: 150 lb
Automatic Turn Off: Yes

APPENDIX B

VEHICLE PREPARATION AND TEST PROCEDURE

When the vehicle was received at Fort Belvoir, MERADCOM, a number of checks were made to assure that it was ready for performance tests. These checks were recorded on a vehicle preparation check sheet. The vehicle was examined for physical damage upon arrival. Before the vehicle was operated, a visual check was made of the entire vehicle. The battery was charged and specific gravities were taken to determine if the batteries were equalized. If not, an equalizing charge was applied to the batteries. The integrity of the internal interconnections and the battery terminals was checked by drawing 300 A or the vehicle manufacturer's maximum allowed current from the battery for 5 min. If the battery terminal or interconnections temperatures rose more than 60° C above ambient, the test was terminated and the terminals were cleaned or the battery was replaced. The batteries were recharged, and a battery-capacity check was made. This test was made in accordance with the battery manufacturer's recommendations. To pass this test, the capacity had to be within 20 percent of manufacturer's published capacity at the published rate.

The wheel alignment was checked, compared, and corrected to the manufacturer's recommended alignment values. The vehicle was weighed and compared with the manufacturer's specified curb weight. The gross vehicle weight was determined by manufacturer's rated pay load.

Each day, before a test, a number of pre-test checks were made and entered on the vehicle data sheet. These data included:

(1) Average specific gravity before and after test.

(2) Tire pressure.

(3) Fifth wheel tire pressure.

(4) Weather information.

(5) Battery temperatures.

(6) Test start time.

(7) Test termination time.

(8) Fifth wheel distance count.

(9) Odometer reading before and after each test.

(10) AC kw used for recharge.

(11) DC amp-hours into battery on recharge.

To prepare for a test, the specific gravities are measured and recorded. The tire pressures are measured. The instrumentation is connected, and power from the instrumentation battery is applied. All instruments are turned on and warmed up, and all data channels are calibrated. The vehicle is towed to the starting point on the track. Weather data are recorded, odometer reading is taken. The test is started and is carried out in accordance with the DOE test and evaluation procedure. When the test is terminated, the test team makes all the proper checks and records all data on the data test sheet for the day's test. After all checks are made, the vehicle is towed back to the charge station and placed on charge for the next day's test.

Measurements of wind velocity and direction and ambient temperature were taken at the beginning and at the end of each day's testing. The local weather station was used for all weather data.

APPENDIX C

VEHICLE TEST RESULT TABULATIONS

Coast-Down Data

Time	Velocity	
(s)	(km/h)	(mi/h)
0	84.3	52.4
3	80.6	50.1
6	77.1	47.9
9	73.2	45.5
12	70.0	43.5
15	65.8	40.9
18	61.6	38.3
21	57.9	36.0
24	54.7	34.0
27	51.3	31.9
30	48.4	30.1
33	45.5	28.3
36	43.1	26.8
39	40.5	25.2
42	38.1	23.7
45	35.7	22.2
48	32.8	20.4
51	30.6	19.0
54	28.2	17.5
57	25.7	16.0
60	23.6	14.7
63	21.2	13.2
66	19.1	11.9
69	17.4	10.8
72	15.4	9.6
75	14.0	8.7
78	12.1	7.5
81	10.3	6.4
84	8.4	5.2
87	6.3	3.9
90	4.2	2.6
93	2.6	1.6
96	0.80	0.5

Speed Vs. Time (0% Discharge)

Time	Velocity	
(s)	(km/h)	(mi/h)
0	0	0
0.2	5.26	3.27
0.6	10.52	6.54
1.3	15.80	9.82
2.2	21.06	13.09
3.3	26.23	16.30
4.5	31.50	19.58
5.7	35.59	22.12
6.6	35.59	22.12
7.2	36.86	22.91
9.0	42.12	26.18
11.1	47.39	29.45
13.8	52.65	32.72
17.4	57.92	36.00
24.9	63.19	39.27
26.4	63.19	39.27
30.3	68.45	42.54
35.4	73.72	45.82
41.7	78.99	49.09
54.6	84.25	52.36
55.3	85.31	53.02

Speed Vs. Time (40% Discharge)

Time	Velocity	
(s)	(km/h)	(mi/h)
0	0	0
0.4	5.26	3.27
0.96	10.52	6.54
1.8	15.80	9.82
2.52	21.06	13.09
3.6	26.23	16.30
4.68	31.50	19.58
4.80	32.15	19.98
6.0	32.15	19.98
7.2	38.86	22.91
9.0	42.12	26.18
10.98	47.39	29.45
13.8	52.65	32.72
15.06	55.06	34.22
15.72	54.14	33.65
18.0	57.92	36.00
21.48	63.19	39.27
24.6	68.45	42.54
28.56	73.72	45.82
34.2	78.99	49.09
43.2	84.25	52.36

Speed Vs. Time (80% Discharge)

Time	Velocity	
(s)	(km/h)	(mi/h)
0	0	0
0.72	5.26	3.27
2.4	10.52	6.54
3.6	15.80	9.82
4.80	21.06	13.09
6.06	26.23	16.30
7.62	31.50	19.58
9.36	36.86	22.91
11.7	42.12	26.18
15.0	47.39	29.45
19.32	52.65	22.72
19.8	53.21	33.07
21.6	53.21	33.07
24.66	57.92	36.00
30.06	63.19	39.27
38.04	68.45	42.54
50.04	73.72	45.82
54.6	75.40	46.86

Acceleration Vs. Velocity Jet 1000
(0% Discharge)

Velocity (km/h)	Acceleration (m/s^2)
10.52	3.17
26.23	1.31
32.57	0.93
35.51	0
36.86	0.735
42.12	0.805
52.65	0.466
62.12	0.164
66.36	0.341
76.46	0.232
82.65	0.080
85.29	0

Velocity (mi/h)	Acceleration (ft/s^2)
6.54	10.4
16.30	4.31
20.24	3.05
22.07	0
22.91	2.41
26.18	2.64
32.72	1.53
38.61	0.537
41.24	1.12
47.52	0.761
51.37	0.264
53.01	0

Acceleration Vs. Velocity Jet 1000
(40% Discharge)

Velocity (km/h)	Acceleration (m/s^2)
10.52	2.19
21.06	1.64
28.32	1.23
32.04	0
33.6	0.872
47.39	0.735
52.65	0.488
54.75	-0.43
57.92	0.491
73.72	0.363
78.99	0.182
83.19	0

Velocity (mi/h)	Acceleration (ft/s^2)
6.54	7.20
13.09	5.37
17.60	4.02
19.91	0
20.88	2.86
29.45	2.41
32.72	1.60
34.03	-1.52
36.00	1.61
45.82	1.19
49.09	0.597
51.70	0

Acceleration Vs. Velocity Jet 1000
(80% Discharge)

Velocity (km/h)	Acceleration (m/s^2)
5.26	1.22
21.06	1.16
31.50	0.920
47.39	0.378
53.20	0
57.92	0.338
65.82	0.187
71.09	0.123
75.51	0

Velocity (mi/h)	Acceleration (ft/s^2)
3.27	4.00
13.09	3.81
19.58	3.02
29.45	1.24
33.06	0
36.00	1.11
40.91	0.615
44.18	0.403
46.93	0

Percent Gradeability At Speed

(0% Discharge)

Velocity		
km/h	mi/h	% Gradeability
10.52	6.54	25.62
26.23	16.30	12.40
35.59	22.12	0.00
42.12	26.18	7.67
52.65	32.72	4.52
57.92	36.00	2.61
68.45	42.54	3.32
78.99	49.09	1.72
82.65	51.37	0.83
85.31	53.02	0.00
	(40% Discharged)	
10.52	6.54	20.26
21.06	13.09	16.78
32.15	19.98	0
36.86	22.91	9.98
42.12	26.18	9.98
52.65	32.72	4.96
54.75	34.03	-4.27
57.92	36.00	3.81
68.45	42.54	4.96
73.72	45.82	3.31
78.99	49.09	1.98
82.82	54.47	0

Percent Gradeability At Speed (Cont'd)
(80% Discharged)

Velocity		
km/h	mi/h	% Gradeability
5.76	3.27	12.51
21.06	13.09	11.92
31.50	19.58	9.40
47.39	29.45	3.85
53.21	33.07	
57.92	36.00	3.45
65.82	40.91	1.91
71.09	44.18	1.25
75.40	46.86	0

Road Energy

Velocity		Road Energy		
km/h	mi/h	MJ/km	kWh	kWh
		(0% Discharged)		
78.99	49.09	0.072	0.258	0.415
68.45	42.54	0.064	0.232	0.374
63.19	39.27	0.067	0.242	0.390
47.39	29.45	0.059	0.214	0.344
36.86	22.91	0.051	0.182	0.293
26.23	16.30	0.047	0.170	0.274
15.80	9.82	0.041	0.148	0.130
5.26	3.27	0.043	0.153	0.135
		(40% Discharged)		
84.23	52.35	0.072	0.258	0.415
63.35	39.37	0.049	0.177	0.285
57.92	36.00	0.044	0.157	0.252
50.02	31.09	0.044	0.160	0.257
31.50	19.58	0.049	0.177	0.285
21.06	13.09	0.044	0.157	0.252
10.52	6.54	0.042	0.150	0.242
2.64	1.64	0.032	0.115	0.185
		(80% Discharged)		
71.09	44.18	0.067	0.241	0.388
65.82	40.91	0.053	0.190	0.306
44.76	27.82	0.050	0.181	0.291
34.13	21.21	0.048	0.173	0.278
23.70	14.73	0.034	0.124	0.199
13.16	8.18	0.026	0.094	0.151
5.26	3.27	0.024	0.088	0.142

Road Power

Velocity		Road Power	
km/h	mi/h	kW	hp
	(0% Discharged)		
78.99	49.09	20.35	27.27
68.45	42.54	15.93	21.35
63.19	39.27	15.22	20.40
47.39	29.45	10.13	13.58
36.86	22.91	6.71	8.99
26.23	16.30	4.48	6.01
15.80	9.82	2.33	3.12
5.26	3.27	0.808	1.08
	(40% Discharged)		
84.23	52.35	21.74	29.15
63.35	39.37	11.19	15.00
57.92	36.00	9.10	12.20
50.02	31.09	8.00	10.72
31.50	19.58	5.59	7.49
21.06	13.09	3.29	4.42
10.52	6.54	1.58	2.12
2.64	1.64	0.305	0.409
	(80% Discharged)		
71.09	44.18	17.12	22.95
65.82	40.91	12.52	16.78
44.76	27.82	8.08	10.84
34.13	21.21	5.93	7.94
23.70	14.73	2.92	3.92
13.16	8.18	1.23	1.65
5.26	3.27	0.434	0.622

I AVG
Jet Van 1000, B Cycle Start/Stop Test
(Average of First Three Cycles)

Time (s)	Current (A)	Time (s)	Current (A)	Time (s)	Current (A)	Time (s)	Current (A)
0.4	47.0	13.2	153.4	26.0	79.2	38.8	34.6
0.8	71.8	13.6	151.0	26.4	81.7	39.2	37.1
1.2	79.2	14.0	151.0	26.8	81.7	39.6	14.8
1.6	89.1	14.4	158.4	27.2	79.2	40.0	12.4
2.0	108.9	14.8	165.8	27.6	69.3		
2.4	106.4	15.2	155.9	28.0	71.8		
2.8	99	15.6	136.1	28.4	71.8		
3.2	101.5	16.0	133.6	28.8	74.2		
3.6	96.5	16.4	123.8	29.2	74.2		
4.0	96.5	16.8	121.3	29.6	76.7		
4.4	99	17.2	126.2	30.0	76.7		
4.8	91.6	17.6	126.2	30.4	79.2		
5.2	86.6	18.0	123.8	20.8	79.2		
5.6	81.7	18.4	99	31.2	79.2		
6.0	79.2	18.8	91.6	31.6	76.7		
6.4	81.7	19.2	104.0	32.0	76.7		
6.8	84.1	19.6	111.4	32.4	64.4		
7.2	94.0	20.0	108.9	32.8	59.4		
7.6	106.4	20.4	101.5	33.2	59.4		
8.0	111.4	20.8	108.9	33.6	61.9		
8.4	108.9	21.2	108.9	34.0	64.4		
8.8	104.0	21.6	106.4	34.4	64.4		
9.2	101.5	22.0	91.6	34.8	66.8		
9.6	101.5	22.4	91.6	35.2	66.8		
10.0	96.5	22.8	89.1	35.6	59.4		
10.4	96.5	23.2	89.1	36.0	47.0		
10.8	99	23.6	89.1	36.4	47.0		
11.2	111.4	24.0	89.1	36.8	47.0		
11.6	116.3	24.4	89.1	37.2	47.0		
12.0	123.8	24.8	81.7	37.6	42.1		
12.4	126.2	25.2	81.7	38.0	34.6		
12.8	146.0	25.6	81.7	38.4	34.6		

I AVG
Jet Van 1000, B Cycle Start/Stop Test
(Average of Next to the Last Three Cycles)

Time (s)	Current (A)	Time (s)	Current (A)	Time (s)	Current (A)	Time (s)	Current (A)
0.4	19.8	12.4	141.1	24.4	86.6	36.4	76.7
0.8	52.0	12.8	138.6	24.8	84.2	36.8	76.7
1.2	91.6	13.2	133.6	25.2	84.2	37.2	76.7
1.6	121.3	13.6	133.6	25.6	84.2	37.6	27.2
2.0	131.2	14.0	128.7	26.0	89.1	38.0	9.9
2.4	141.1	14.4	126.2	26.4	104.0	38.4	12.4
2.8	148.5	14.8	133.6	26.8	106.4	38.8	29.7
3.2	143.6	15.2	131.2	27.2	84.2	39.2	34.6
3.6	131.2	15.6	128.7	27.6	76.7	39.6	27.2
4.0	136.1	16.0	136.1	28.0	79.2	40.0	24.8
4.4	136.1	16.4	136.1	28.4	84.2	40.4	22.3
4.8	146.0	16.8	133.6	28.8	79.2	40.8	22.3
5.2	151.0	17.2	133.6	29.2	54.4	41.2	14.8
5.6	146.0	17.6	133.6	29.6	52.0	41.6	14.8
6.0	146.0	18.0	136.1	30.0	49.5	42.0	0
6.4	151.0	18.4	146.0	30.4	49.5		
6.8	153.4	18.8	146.0	30.8	61.9		
7.2	153.4	19.2	143.6	31.2	74.2		
7.6	136.1	19.6	141.1	31.6	74.2		
8.0	133.6	20.0	138.6	32.0	76.7		
8.4	133.6	20.4	136.1	32.4	76.7		
8.8	133.6	20.8	133.6	32.8	79.2		
9.2	133.6	21.2	131.2	33.2	86.6		
9.6	136.1	21.6	131.2	33.6	89.1		
10.0	133.6	22.0	128.7	34.0	89.1		
10.4	128.7	22.4	108.9	34.4	89.1		
10.8	126.2	22.8	104.0	34.8	86.6		
11.2	126.2	23.2	101.5	35.2	86.6		
11.6	126.2	23.6	96.5	35.6	79.2		
12.0	141.1	24.0	96.5	36.0	79.2		

Battery Voltage (AVG)
Jet Van 1000 B Cycle Start/Stop
(Average of First Three Cycles)

Time (s)	BV (V)	Time (s)	BV (V)
0.4	15.04	38.0-39.2	147.1
0.8	149.3	39.6-40.0	148.2
1.2	147.1	40.4-41.2	149.3
1.6	146.0		
2.0	143.8		
2.4-4.0	142.7		
4.4-6.0	143.8		
6.4-8.4	142.7		
8.7	141.6		
9.2-10.4	142.7		
10.8	143.8		
11.2	142.7		
11.6	142.7		
12.0	141.6		
12.4	141.6		
12.8	140.5		
13.2	141.6		
13.6	140.5		
14.0	140.5		
14.4-15.2	139.4		
15.6-16.8	140.5		
17.2-18.0	139.4		
18.4-19.2	141.6		
22.4-26.0	142.7		
26.4-27.6	143.8		
28.0-29.2	144.9		
29.6	143.8		
30.0-30.4	144.9		
30.8	146.0		
21.2-31.6	144.9		
32.0-37.6	146.0		

Battery Voltage (AVG)
Jet Van 1000 B Cycle Start/Stop
(Average of Next to the Last Three Cycles)

Time (s)	BV (V)	Time (s)	BV (V)	Time (s)	BV (V)
0.4	139.4	13.6-14.8	109.8	33.6	114.2
0.8	136.1	15.2-16.4	108.7	34.0	113.1
1.2	131.2	16.8-18.0	107.6	34.4	113.1
1.6	126.2	18.4	106.5	34.8	112.0
2.0	120.1	18.8	105.4	35.2	112.0
2.4	118.6	19.2-20.4	104.3	35.6	112.0
2.8	116.4	20.8-22.4	105.4	36.0	113.1
3.2	114.2	22.8	107.6	36.4	113.1
3.6	115.3	23.2-24.4	109.8	36.8-38.0	114.2
4.0	114.4	24.8	112.0	38.4	127.3
4.4	115.3	25.2-26.4	113.1	38.8	128.4
4.8	115.3	26.8	110.9	39.2	128.4
5.2	114.2	27.2	108.7	39.6	126.2
5.6	112.0	27.6	108.7	40.0	126.2
6.0	112.0	28.0	115.3	40.4	128.4
6.4	112.0	28.4	114.4	40.8	128.4
6.8	110.9	28.8	114.4	41.2	129.5
7.2	110.9	29.2	115.3	41.6	129.5
7.6	109.8	29.6	118.6	42.0	132.8
8.0	113.1	30.0	120.7	42.4-44.0	133.9
8.4	113.1	30.4	120.7		
8.8	113.1	30.8	121.8		
9.2	112.0	31.2	120.7		
9.6	112.0	31.6	118.6		
10.0	110.9	32.0	116.4		
10.4-12.4	112.0	32.4	115.3		
12.8	109.8	32.8	115.3		
13.2	108.7	33.2	115.3		

Power (AVG)
Jet Van 1000 B Cycle Start/Stop
(Average of First Three Cycles)

Time (s)	Power (W)	Time (s)	Power (W)	Time (s)	Power (W)	Time (s)	Power (W)
0.4	7469	12.4	20396	24.0	11778	35.6	6607
0.8	10342	12.8	20396	24.4	11491	36.0	6607
1.2	11203	13.2	20109	24.8	11778	36.4	6607
1.6	12352	13.6	20971	25.2	11204	36.8	5745
2.0	13789	14.0	21545	25.6	11491	37.2	4884
2.4	13502	14.4	22694	26.0	11491	37.6	4884
2.8	13502	14.8	19543	26.4	11204	38.0	4884
3.2	13502	15.2	18385	26.8	10629	38.4	5171
3.6	12927	15.6	18385	27.2	10342	38.8	5458
4.0	13214	16.0	17811	27.6	10054	39.2	3734
4.4	12927	16.4	16087	28.0	10629	39.6	0
4.8	12352	16.8	16949	28.4	10629	40.0	0
5.2	11778	17.2	16949	28.8	10916		
5.6	11203	17.6	15225	29.2	10916		
6.0	11203	18.0	13789	29.6	10629		
6.4	11491	18.4	13789	30.0	10916		
6.8	13789	18.8	14364	30.4	11204		
7.2	14651	19.2	14364	30.8	11204		
7.6	15225	19.6	15800	31.2	10916		
8.0	14651	20.0	15800	31.6	10054		
8.4	14076	20.4	15513	32.0	8331		
8.8	13789	20.8	14938	32.4	8331		
9.2	13214	21.2	13214	32.8	8905		
10.0	12927	21.6	13214	33.2	8905		
10.4	14364	22.0	12927	33.6	9193		
10.8	14938	22.4	12927	34.0	9193		
11.2	15513	22.8	12353	34.4	9480		
11.6	16662	23.2	12640	34.8	9480		
12.0	17811	23.6	12640	35.2	6894		

Power (AVG)
Jet Van 1000 B Cycle Start/Stop
(Average of Next to the Last Three Cycles)

Time (s)	Power (W)	Time (s)	Power (W)	Time (s)	Power (W)	Time (s)	Power (W)
0.4	2298	10.4	13214	20.4	13789	30.4	5458
0.8	5171	10.8	12927	20.8	13502	30.1	6320
1.2	8331	11.2	12927	21.2	13214	31.2	7756
1.6	9767	11.6	13214	21.6	13214	31.6	7756
2.0	11778	12.0	14363	22.0	13214	32.0	8044
2.4	12640	12.4	14076	22.4	10916	32.4	8044
2.8	13502	12.8	13789	22.8	10629	32.8	8618
3.2	13214	13.2	13502	23.2	10342	33.2	9193
3.6	12353	13.6	13214	23.6	10054	33.6	9480
4.0	12977	14.0	13214	24.0	10054	34.0	9480
4.4	12977	14.4	12927	24.4	9193	34.4	9480
4.8	14938	14.8	13502	24.8	8905	34.8	9193
5.2	14363	15.2	13502	25.2	8905	35.2	8905
5.6	14076	15.6	13214	25.6	8905	35.6	8331
6.0	14363	16.0	14076	26.0	9480	36.0	8044
6.4	14651	16.4	13789	26.4	10916	36.4	8044
6.8	14651	16.8	13789	26.8	11203	36.8	8044
7.2	14938	17.2	13502	27.2	9480	37.2	8044
7.6	13502	17.6	13502	27.6	8331	37.6	4022
8.0	13502	18.0	13789	28.0	8331	38.0	1149
8.4	13502	18.4	14651	28.4	8905	38.4	1436
8.8	13502	18.8	14651	28.8	8618	38.8	3160
9.2	13502	19.2	14363	29.2	6033	39.2	3735
9.6	13789	19.6	14363	29.6	5745	39.6	3160
10.0	13502	20.0	14076	30.0	5745	40.0	2582
						40.4	2298
						40.8	2298
						41.2	2973
						41.6	2585
						42.0	0

Constant-Speed Battery Performance Data

	First 25%	Last 25%
25 mi/h Range Run (26 Oct 78)		
AVG I	84.5 A	88.6 A
AVG V	135.4 V	117.9 V
AVG P	11,661.8 W	10,222.7 W
35 mi/h Range Run (7 Nov 78)		
AVG I	133.5 A	123.2 A
AVG V	132.9 V	117.8 V
AVG P	18,313.6 W	15,215.6 W
44 mi/h Range Run (27 Oct 78)		
AVG I	233.4 A	204.5 A
AVG V	126.9 V	109.4 V
AVG P	28,262.8 W	20,766.7 W

APPENDIX D

OVERVIEW OF INITIAL PROPULSION BATTERY PROBLEMS

The Jet Van 1000 arrived for test equipped with experimental 168.8-Ah batteries (75 A for 135 min), which had a single-point watering system. These batteries had a specific gravity (after charge) which ranged from 1.55 to 1.250. Initial problems arose with leakage of electrolyte in the single-point watering system. Adding water to the batteries through the single-point system caused dilution problems with some of the cells because of uneven watering. The 3-cell battery modules were grouped with 6 in the front under the hood, 8 in back of the seats under the floor board, and 10 at the rear under the floor board. The front 6 were most diluted because this is where the single-point water entered the system. The next 8 were less diluted, and the rear 10 were slightly less diluted.

The charge-discharge testing of the battery pack was conducted according to the procedures outlined in Appendix F, MERADCOM Report 2244.* These initial tests of the Globe Union battery pack fell short of the specified 135 min at a 75-A capacity. The minimum required for testing at MERADCOM (greater than 80 percent of manufacturer's specified capacity) was not met on seven charge-discharge cycles. Attempts at equalization as well as additional cycling of the pack did not bring the spread of specific gravities of a charged battery to within the desired ± 0.010 from average range. Globe Union suggested various charge current regimes for the batteries, to no avail. Globe Union then replaced the initial battery pack with 24 new batteries and 2 spares. The single-point watering system was not used for this new battery pack. Initial examination of the battery modules uncovered two defective ones. Equalization and top-off charging was performed, and the battery was tested for capacity, which was now agreed upon as being 168.8 Ah (75 A for 135 min). The battery did not make 80 percent of this ampere-hour rating for its first discharge. The battery was cycled the equivalent of six more times before it made the prerequisite 80 percent of capacity upon discharge. Vehicle tests from 23 Oct 78 on were run after the batteries made this capacity run.

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* F. J. Dowgiallo, Jr., C. E. Bailey, Jr., J. R. Snellings, and W. H. Blake, "Baseline Tests on the JAVA Metro Electric Passenger Vehicle," MERADCOM Report 2244 (May 1978).

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